

(12) **United States Patent**
Kaufman et al.

(10) **Patent No.:** **US 9,079,555 B2**
(45) **Date of Patent:** **Jul. 14, 2015**

(54) **METHODS AND APPARATUS TO DISRUPT THE ENGINE OF A VEHICLE**

(56) **References Cited**

(75) Inventors: **Steven L. Kaufman**, Port Hueneme, CA (US); **Jack E. White**, Santa Barbara, CA (US); **Vincent C. Hougo**, Santa Barbara, CA (US)

(73) Assignee: **Raytheon Company**, Waltham, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 636 days.

(21) Appl. No.: **13/372,073**

(22) Filed: **Feb. 13, 2012**

(65) **Prior Publication Data**

US 2012/0173120 A1 Jul. 5, 2012

Related U.S. Application Data

(63) Continuation-in-part of application No. 12/581,087, filed on Oct. 16, 2009, now Pat. No. 8,116,966.

(51) **Int. Cl.**
B60R 25/04 (2013.01)
F02D 41/04 (2006.01)
B60R 25/045 (2013.01)

(52) **U.S. Cl.**
CPC **B60R 25/04** (2013.01); **B60R 25/045** (2013.01); **F02D 41/042** (2013.01)

(58) **Field of Classification Search**
CPC F02D 41/042; B60R 25/04; B60R 25/045
USPC 701/36, 108, 112; 180/167, 168, 169
See application file for complete search history.

U.S. PATENT DOCUMENTS

4,236,594	A *	12/1980	Ramsperger	180/167
4,619,231	A *	10/1986	Stolar et al.	123/333
4,660,528	A *	4/1987	Buck	123/333
5,218,367	A *	6/1993	Sheffer et al.	342/457
5,293,527	A *	3/1994	Sutton et al.	340/12.1
5,311,197	A *	5/1994	Sorden et al.	342/457
5,513,244	A *	4/1996	Joao et al.	455/404.1
5,533,589	A *	7/1996	Critzer	180/287
5,832,394	A *	11/1998	Wortham	701/1
5,835,868	A *	11/1998	McElroy et al.	701/2
5,907,290	A *	5/1999	Turner et al.	340/12.1
5,933,075	A *	8/1999	Ditson	340/426.11
5,937,823	A *	8/1999	Reeder et al.	123/335

(Continued)

FOREIGN PATENT DOCUMENTS

FR	2 793 973	A1	1/2000
WO	WO 99/43513		9/1999
WO	WO 2011/046777	A1	4/2011

OTHER PUBLICATIONS

U.S. Appl. No. 12/581,087, filed Oct. 16, 2009.

(Continued)

Primary Examiner — Hieu T Vo

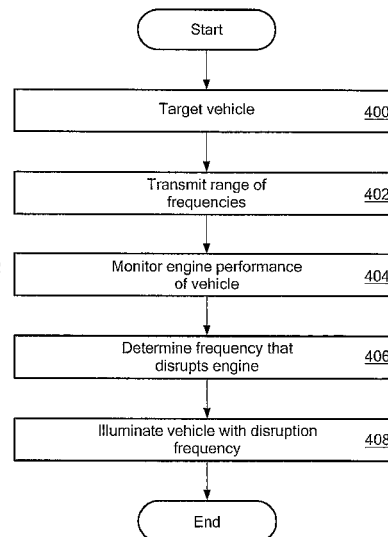
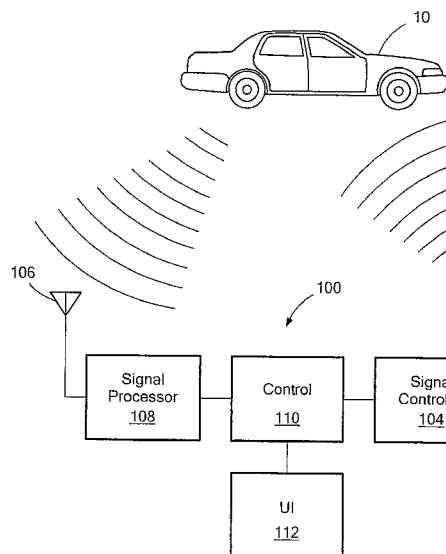
Assistant Examiner — Sherman Manley

(74) *Attorney, Agent, or Firm* — Daly, Crowley, Mofford & Durkee, LLP

(57) **ABSTRACT**

Methods and apparatus to transmit a range of frequencies targeting a vehicle, monitoring performance of an engine of the vehicle, determining a first frequency in the range of frequencies that disrupts operation of the engine, and dwelling on the first frequency to disrupt the engine, reducing power and continuing to dwell at the first frequency to maintain disruption of the engine.

18 Claims, 5 Drawing Sheets



(56)

References Cited

U.S. PATENT DOCUMENTS

5,952,600	A *	9/1999	Herr	89/1.11
6,072,248	A *	6/2000	Muise et al.	307/10.2
6,232,874	B1 *	5/2001	Murphy	340/426.19
6,232,884	B1 *	5/2001	Gabbard	340/12.27
6,371,000	B1 *	4/2002	Hutmacher et al.	89/1.11
6,647,328	B2 *	11/2003	Walker	701/36
6,862,524	B1 *	3/2005	Nagda et al.	701/420
6,897,762	B2 *	5/2005	Howells	340/5.31
6,965,816	B2 *	11/2005	Walker	701/16
6,995,667	B2 *	2/2006	He et al.	340/539.13
7,049,709	B2 *	5/2006	Boggs	307/10.2
7,091,821	B2 *	8/2006	Lessard et al.	340/5.61
7,182,362	B2 *	2/2007	Yeakel	280/433
7,554,442	B2 *	6/2009	Twitchell, Jr.	340/539.26
7,598,846	B2 *	10/2009	Griffin et al.	340/426.11
7,825,795	B2 *	11/2010	Peel et al.	340/539.16
7,916,016	B2 *	3/2011	Auerbach et al.	340/539.26
8,387,735	B2 *	3/2013	Elson	180/167
2001/0040503	A1 *	11/2001	Bishop	340/426
2002/0070850	A1 *	6/2002	Michala et al.	340/426
2005/0184858	A1 *	8/2005	Griffin et al.	340/426.11
2005/0195069	A1 *	9/2005	Dunand	340/5.61
2005/0242971	A1 *	11/2005	Dryer	340/870.11
2005/0263120	A1	12/2005	Fifelski et al.	
2006/0250272	A1 *	11/2006	Puamau	340/825.69

2006/0265128	A1 *	11/2006	Miller	701/213
2007/0155327	A1 *	7/2007	Twitchell, Jr.	455/41.2
2008/0015744	A1 *	1/2008	Lund	701/2
2008/0223641	A1 *	9/2008	Elson	180/167
2009/0085731	A1 *	4/2009	Bogges	340/426.12
2009/0219135	A1 *	9/2009	Harvey et al.	340/5.82
2009/0248222	A1 *	10/2009	McGarry et al.	701/2
2009/0322510	A1 *	12/2009	Berger et al.	340/539.1
2011/0093180	A1	4/2011	Hougo et al.	
2011/0133912	A1	6/2011	Tesman	

OTHER PUBLICATIONS

International Search Report for International Application No. PCT/US2010/051520, filed Oct. 5, 2010, International Search Report dated Feb. 3, 2011, 4 pages.

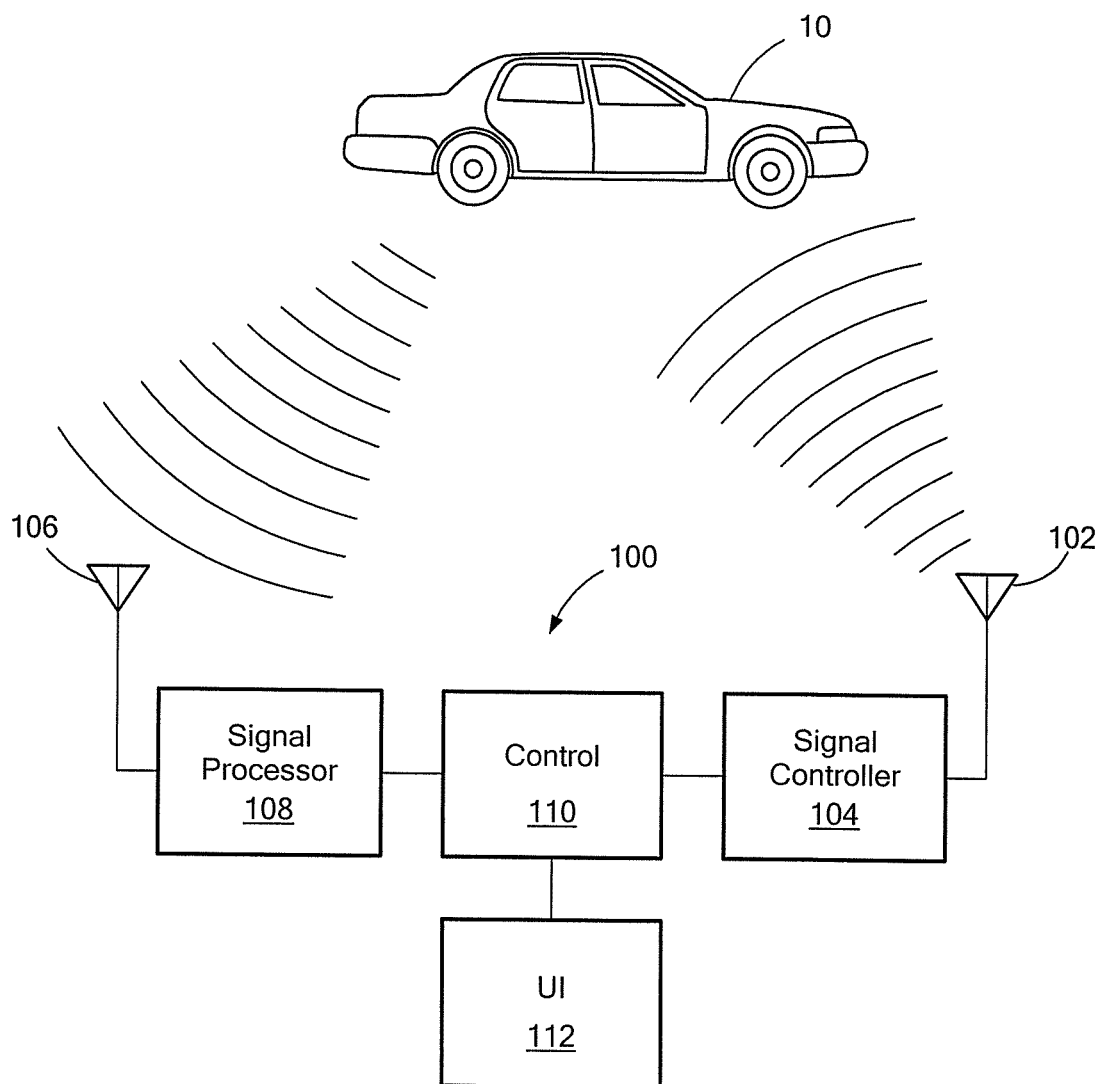
Written Opinion of the International Searching Authority for International Application No. PCT/US2010/051520, filed Oct. 5, 2010, Written Opinion dated Feb. 3, 2011, 6 pages.

Response to the extended European search filed on Sep. 12, 2013 in European Patent Application No. 12166887.5, 22 pages.

European Patent Office Search Report, Application No. 12166887.5-1655/2625952, Jul. 17, 2013, 9 pages.

EP Patent Application No. 12 166 887.5-1655 Notice of Allowance dated Jan. 12, 2015 22 pages.

* cited by examiner

**FIG. 1**

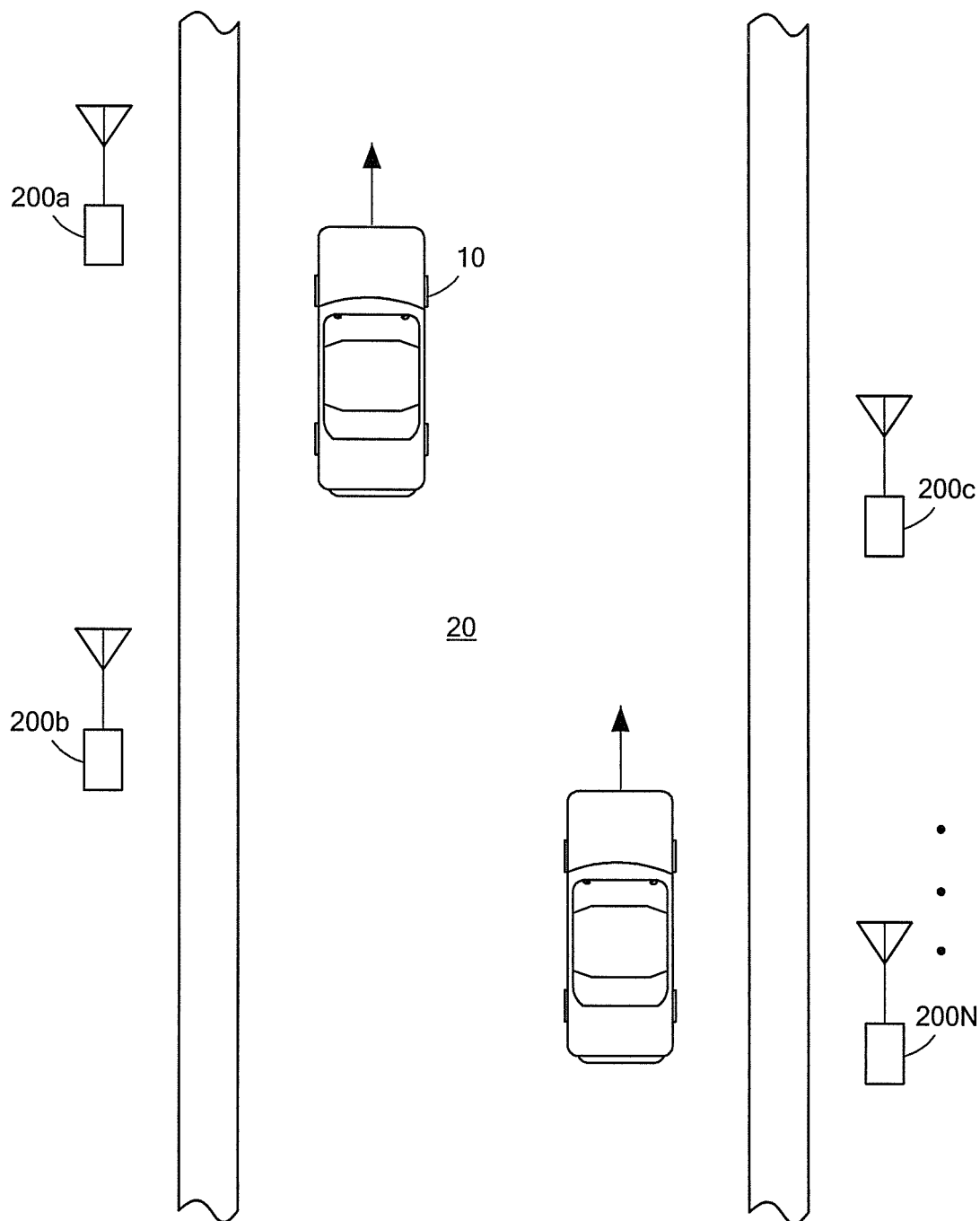


FIG. 2

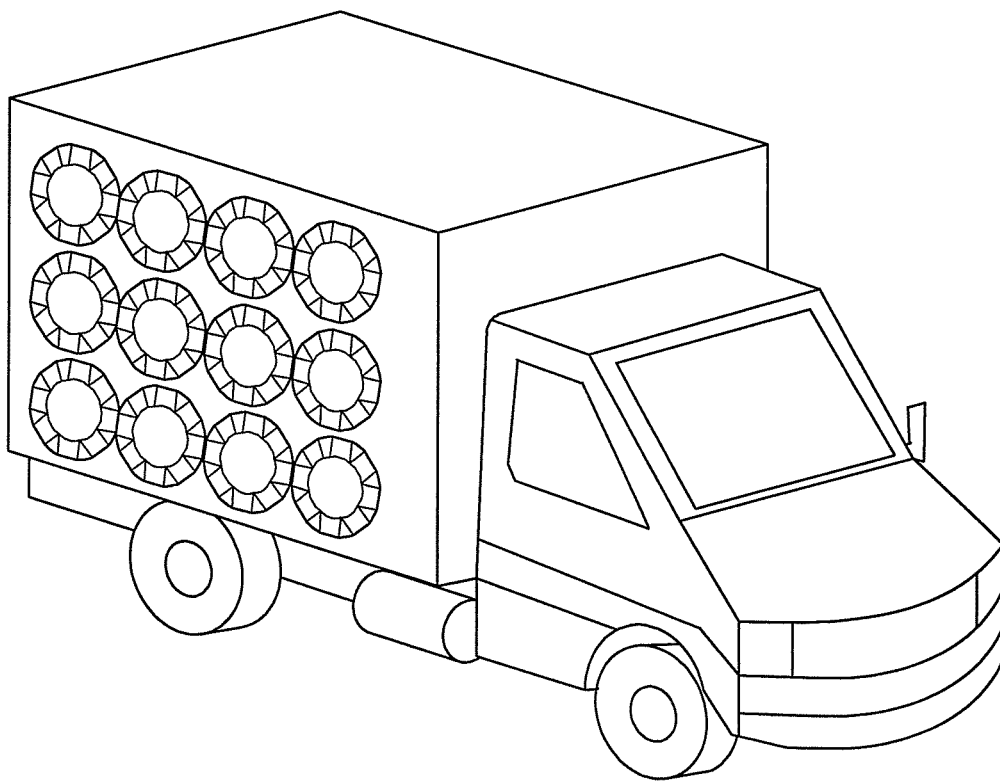
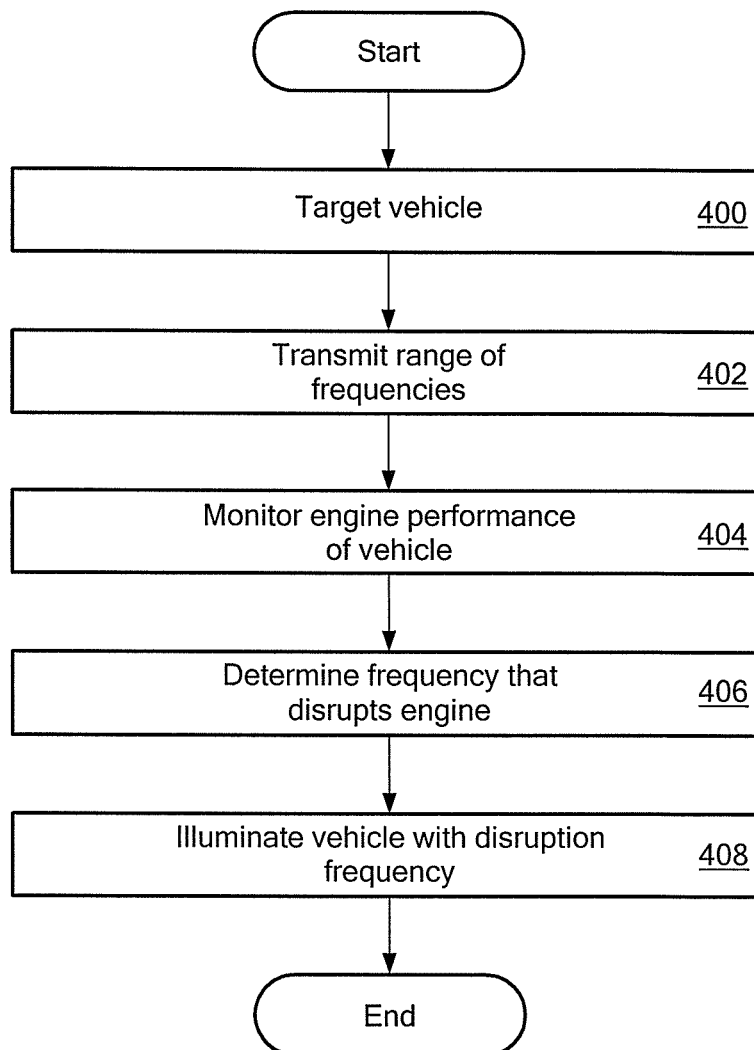
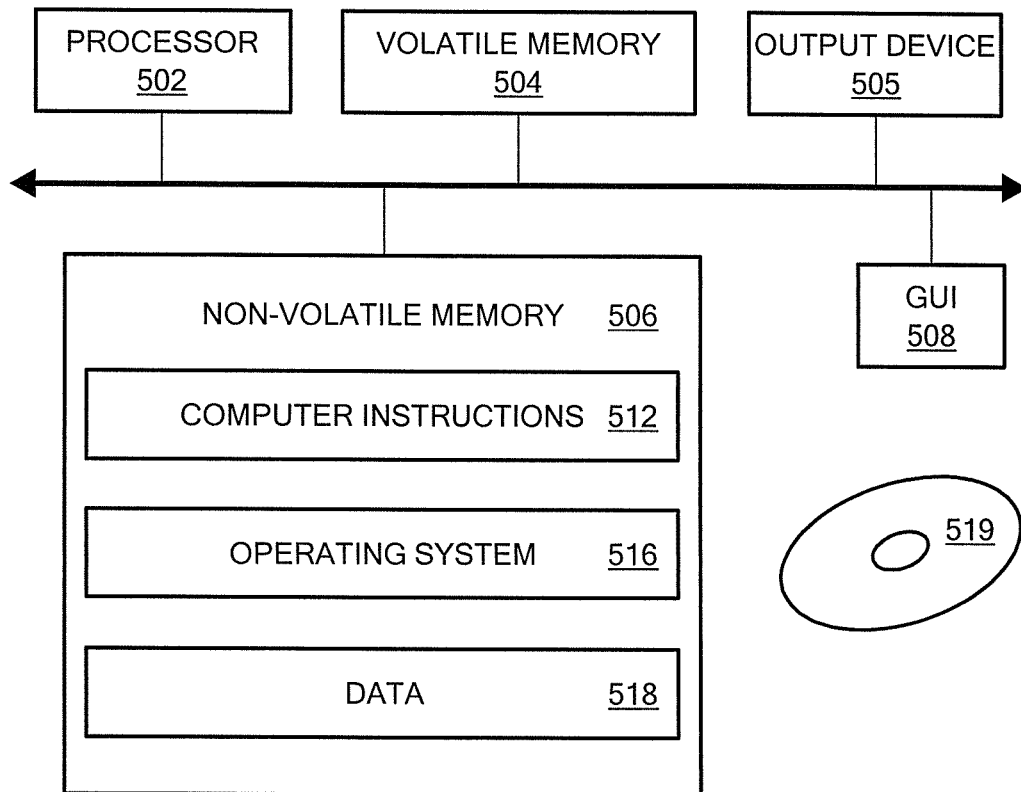


FIG. 3

**FIG. 4**

**FIG. 5**

1

METHODS AND APPARATUS TO DISRUPT THE ENGINE OF A VEHICLE

CROSS REFERENCE TO RELATED APPLICATIONS

The present application is a continuation-in-part of U.S. patent application Ser. No. 12/581,087, filed on Oct. 16, 2009, which is incorporated herein by reference.

BACKGROUND

As is known in the art, there are a variety of techniques to deal with vehicle drivers that do not operate their vehicle safely or have bad intentions. Exemplary techniques include road blocks, barricades, and tack strips. However, these techniques may have limited effectiveness and may present safety issues. For example, obstacles such as barricades, patrol cars, nets, and tack strips on a public road, can create dangerous conditions if vehicle operators escalate the situation. A driver may attempt to go through a roadblock by speeding through barricades. Furthermore, roadblocks typically require the services of law enforcement officers for setup, which requires advance notice and planning. In the event that the vehicle forces its way through the barricade, officers may engage in a dangerous high-speed pursuit.

Other known techniques for stopping vehicles include the use of electromagnetic pulse (EMP) or high power microwaves to disrupt the electronic components of the vehicles. However, the use of EMP to disable a moving vehicle requires high energy levels that are difficult to deploy in the field. Similarly, the use of high power microwaves requires a high power microwave source that is difficult to deploy and package. Furthermore, EMP and high power microwaves may be unsafe for people in the area of application. When high power microwaves or EMPs are used to stop a moving vehicle, microwave radiation is directed toward the vehicle to disable or inhibit electronic components of the vehicle. It is difficult to direct the microwave energy directly against a single vehicle. Thus, when the microwave radiation is adapted to disable a particular vehicle's electronic components, all or many of the vehicles in the vicinity of the targeted vehicle may also be temporarily or permanently disabled. Disabling non-targeted vehicles may become a hazard to law enforcement personnel and public.

SUMMARY

The present invention provides method and apparatus for disabling a vehicle by disrupting an engine control unit (ECU). In an exemplary embodiment, a receiver is used to monitor engine parameters, such as ignition timing, to detect disruption caused by a particular frequency transmitted by a transmit antenna. The system can dwell on this frequency to disable the vehicle. With this arrangement, a vehicle can be quickly and safely disabled. While exemplary embodiments of the invention are shown and described in conjunction with particular frequencies, power, vehicles and engine control unit characteristics, it is understood that embodiments of the invention are applicable to applications in which it is desirable to disrupt and/or stop an engine.

In one aspect of the invention, a system comprises: a transmit antenna, a controller to control frequencies transmitted by the transmit antenna, a receive antenna, and a signal processor to process information from the receive antenna to identify a frequency transmitted by the transmit antenna that disrupts operation of an engine, wherein the controller controls the

2

signal transmitted by the transmit antenna to dwell on the frequency that disrupts the engine.

In another aspect of the invention, a vehicle checkpoint system comprises: at least one system to disable vehicles, comprising: a transmit antenna, a controller to control frequencies transmitted by the transmit antenna, a receive antenna, and a signal processor to process information from the receive antenna to identify a frequency transmitted by the transmit antenna that disrupts operation of an engine, wherein the controller controls the signal transmitted by the transmit antenna to dwell on the frequency that disrupts the engine.

In a further aspect of the invention, a method comprises: transmitting a range of frequencies targeting a vehicle, monitoring performance of an engine of the vehicle, determining a first frequency in the range of frequencies that disrupts operation of the engine from the engine performance monitoring, and dwelling on the first frequency to maintain disruption of the engine.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing features of this invention, as well as the invention itself, may be more fully understood from the following description of the drawings in which:

FIG. 1 is a schematic representation of an exemplary vehicle disruption system in accordance with exemplary embodiments of the invention;

FIG. 2 is a schematic representation of a checkpoint having at least one vehicle disruption system;

FIG. 3 is a pictorial representation of a transmit antenna array that can form a part of the system of FIG. 1;

FIG. 4 is a flow diagram showing an exemplary sequence of steps for implementing vehicle disruption in accordance with exemplary embodiments of the invention; and

FIG. 5 is a schematic representation of an exemplary computer that can perform at least of the processing for vehicle disruption.

DETAILED DESCRIPTION

In general, exemplary embodiments of the invention enable disruption of an engine control unit (ECU) of a vehicle. In one embodiment, a system employs a scanning VHF/UHF signal using RF tones to disrupt the vehicle ECU, detect the disrupting frequency, and dwell on the disrupting frequency to bring the vehicle to a stop. Exemplary embodiments of the system can be located at fixed location, such as a checkpoint, a mobile vehicle, or other platform.

FIG. 1 shows an exemplary vehicle disruption system 100 in accordance with exemplary embodiments of the invention. The system includes a transmit antenna 102 to transmit a range of frequencies while illuminating a target 10, such as vehicle. A signal controller 104 controls the characteristics of the transmitted signals.

A receive antenna 106 receives a signal emitted by the internal combustion engine ignition system of the vehicle 10. A signal processor 108 is coupled to the receive antenna 106 and to a control module 110 that controls overall operation of the system. A user interface 112 is coupled to the controller 110 to enable a user to interact with the system.

In general, signals emitted by the engine correspond to the vehicle ignition timing and other characteristics that factor in to frequency susceptibility of the internal combustion engine. The signal processor 108 analyzes the received information and determines scan and dwell tones that can be transmitted by the transmit antenna 102 to initiate disruption and eventual default of the ECU controlling the ignition timing of the

internal combustion engine. In general, the signal controller **104** controls scan and dwell signal transmission over a defined frequency range to determine the optimally disruptive frequency tone by monitoring the ignition response. Continued signal transmission at the frequency of susceptibility results in ECU default until the signal is removed.

In one embodiment, a selected area is radiated for one or more specific vehicles. Since the transmitted frequency corresponds to engine timing for a specific vehicle, the system can disrupt a targeted vehicle in the midst of several vehicles without affecting the non-targeted vehicles. With an array for the transmission, the beam width can be narrow or wide depending on the application.

It is understood that with feedback from engine operation, it can be determined what frequency is effective to disrupt the engine ECU. It is believed that signals are coupling into the ECU through its wiring harness to cause the disruptive effect. It is believed that the disruptions are temporary because the communication between the ECU and sensors are 'jammed'.

By disrupting the vehicle ECU, the engine will stop in milliseconds. The ECU can go into a default mode in seconds, thereby requiring much less to power (e.g., 8 dB) to maintain disruption to the ECU and prevent the engine from restarting. Upon removal of the disrupting signal, the ECU can regain normal functionality without damage.

The closed loop feedback determines the most disruptive frequency tone to produce an ECU default. In addition, this results in an inability of the ECU to reacquire at a much lower power level. The disruptive dwell tone may be modulated to reduce the power level compared with a continuous wave transmitted tone.

It has been found that most ECUs have susceptible frequencies that fall within VHF and UHF bands. In one embodiment, a transmitter includes a power combined GaN Amplifier for provide CW power in the order of 170 kW for ECU disruption at about 100 m and for 10 m about 17 W.

In one embodiment shown in FIG. 2, a series of vehicle disruption systems **200a-N** are distributed along a vehicle pathway **20**. The distributed systems are synchronized by a remote receiver/processor to focus the energy at a target vehicle/ECU **10**. With this arrangement, higher levels of energy are present at the target **20** to minimize energy levels in the area in the pathway vicinity. In one embodiment, a single receive antenna monitors engine operation of a targeted vehicle. This arrangement is well suited for vehicle checkpoints, such as border crossings.

In an exemplary embodiment, vehicle disruption systems are hidden and/or camouflaged. An aggressive vehicle can be disabled from a hidden disruption system. An operator of the vehicle may not even be aware that the vehicle has been targeted for disruption.

It should be noted that no a priori information is required by exemplary embodiments of a vehicle disruption system. The system **100** illuminates the vehicle over a range of frequencies, monitors a response of the vehicle engine, and identifies the frequency of the signal that disrupts operation of the vehicle ECU.

It is understood that embodiments of an inventive vehicle disruption system can be used for any vehicle having electronic ignition control. Exemplary vehicles include automobiles, motorcycles, boats, armored vehicles, snowmachines, and the like.

A variety of suitable antennas can be used. In one particular embodiment, a transmit antenna comprises a series of antennas identified as Part No. FRF-110A from First RF corporation in Boulder, Colo. In one embodiment shown in FIG. 3, the antennas are arranged in a 3x4 lattice on a mobile platform

shown as a truck. In one embodiment, the receive antenna is an omni operating at frequencies higher than those of the transmit antenna.

FIG. 4 shows an exemplary sequence of steps for providing vehicle disruption in accordance with exemplary embodiments of the invention. In step **400**, an object of interest, such as a vehicle, is targeted. The target is illuminated by transmitting signals in a range of frequencies in step **402**. During illumination of the vehicle, in step **404** a receive antenna monitors operation of the engine, such as ignition timing. In step **406**, the information from the receive antenna is used to detect disruption of engine operation due to the signals from the transmit antenna. More particularly, the system analyzes operation of the engine to identify the specific frequency that produces the most disruption. It is understood that transmit and receive operations are coordinated in a known manner. In step **408**, the signal of maximum disruption is transmitted by the transmit antenna to disable the vehicle. Once the vehicle is disabled, the power level can be decreased to a level that prevents restart of the engine.

It is understood that engine operating characteristics can be stored in a database, as described in U.S. patent application Ser. No. 12,581,087, which is incorporated herein by reference.

Referring to FIG. 5, a computer includes a processor **502**, a volatile memory **504**, an output device **505**, a non-volatile memory **506** (e.g., hard disk), and a graphical user interface (GUI) **508** (e.g., a mouse, a keyboard, a display, for example). The non-volatile memory **506** stores computer instructions **512**, an operating system **516** and data **518**, for example. In one example, the computer instructions **512** are executed by the processor **502** out of volatile memory **504** to perform all or part of the processing described above. An article **519** can comprise a machine-readable medium that stores executable instructions causing a machine to perform any portion of the processing described herein.

Processing is not limited to use with the hardware and software described herein and may find applicability in any computing or processing environment and with any type of machine or set of machines that is capable of running a computer program. Processing may be implemented in hardware, software, or a combination of the two. Processing may be implemented in computer programs executed on programmable computers/machines that each includes a processor, a storage medium or other article of manufacture that is readable by the processor (including volatile and non-volatile memory and/or storage elements), at least one input device, and one or more output devices. Programs may be implemented in a high level procedural or object-oriented programming language to communicate with a computer system. However, the programs may be implemented in assembly or machine language. The language may be a compiled or an interpreted language and it may be deployed in any form, including as a stand-alone program or as a module, component, subroutine, or other unit suitable for use in a computing environment. A computer program may be deployed to be executed on one computer or on multiple computers at one site or distributed across multiple sites and interconnected by a communication network. A computer program may be stored on a storage medium or device (e.g., CD-ROM, hard disk, or magnetic diskette) that is readable by a general or special purpose programmable computer for configuring and operating the computer when the storage medium or device is read by the computer to perform processing.

Having described exemplary embodiments of the invention, it will now become apparent to one of ordinary skill in the art that other embodiments incorporating their concepts

5

1. A system, comprising:

- 10

6

9. The system according to claim 8, wherein the at least one system to disable vehicles is hidden.

- 40

* * * * *